Dynamic change of arborous species diversity in natural secondary forests after selective cutting on the north slope of Changbai Mountain, Northeast China

JIN Yong-huan[1], ZHOU Li[1], GU Hui-yan[1,2], DAI Li-min[1], SHEN Guang-ri[3], LIU Jun[4]

[1]*Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, P. R. China*

[2]*Northeast Forestry University, Harbin 150040, P. R. China*

[3]*Institute of Forest Inventory and Planning of Yanbian, Jilin Yanji 133000, P. R. China*

[4]*Institute of Changbai Mountain National Reserve of Jilin, Antu 133613, P. R. China*

Abstract: The community characteristics of natural secondary forests on the north slope of Changbai Mountain after selective cutting were investigated, and the dynamics of arborous species diversity during the restoration period of 28 years were studied. The results showed that the arborous species richness (S) had little change and kept the range of 18-22 all along, the Simpson index (D) of the secondary layer and regeneration layer and whole stand had similar trends of change, but that of the canopy layer descended slowly in initial 15 years and had little change later, and the change of diversity index was not obvious and the Shannon-Wiener index (H′) fluctuated in a very small scopes (H′ ± 10%).

Keywords: Arborous species diversity; Natural secondary forests; Selective cutting; Northeast China

CLC number: S718 **Document code**: A **Article ID**: 1007-662X(2003)04-0299-04

Introduction

The change of species diversity, as an important component in restoration ecology, shows the process and mechanism of the landscape function or dysfunction. Exploitation and utilization of natural resources, together with general human activities have changed ecosystems (Li 1997). Human disturbance not only destroys and changes the habitat of all forms of biota but also has impacts on the conservation of biodiversity. Maarten *et al.* (1995) studied the variety of plant diversity along the different succession gradient in alpine quercetum in Costarica. In China, It is encouraged to grow a number of plant species and individuals in early stage in secondary closed forest. With passage of time, the composition of the families in the closed forest has considerably changed, and the family-species has observably increased (Gao *et al.* 1992). The community diversity indices on the abandoned cropland increased steadily when the succession developed from the annual herbosa to the mixed broad-leaved deciduous forest. After the stage of the mixed broad-leaved deciduous forest, all the diversity indexes except species abundance decreased more or less (Gao *et al.* 1997). There were many studies related to the dynamic of biodiversity after clear cutting of forest (Shi 1998; Luo 1997; Zhang & Li 2000), but few reports related to the dynamic of biodiversity after selective cutting.

The Changbai Mountain forest is a major component of the forested land in northeast China. Here the broad-leaved/Korean pine (*Pinus koraiensis*) forest dominates. Since the1950s, large-scale clear cutting and selective cutting have been made in this area, which resulted in gradual degradation of the forest ecosystem (Zhang *et al.* 1999). The aims of this study is to reveal the degradation and succession process of the forest disturbed by the human being by analyzing the dynamics of biodiversity in secondary forest, and to provide scientific data for the conservation of biodiversity and sustainable development of forest.

Site description

This study was conducted in Changbai Mountain, China (127°06' to 128°55' E, 41°20' to 42°28' N). The altitude of this site is in range of 500-1100 m, and the gradient is in range of 1-5°. The broad-leaved Korean pine forest is naturally distributed in this area. The soil type is Dark Brown Soil. This area belongs to a temperate continental monsoonal climate. Mean annual temperature is -7.3-4.9 °C. Annual precipitation is 600-900 mm, sunshine duration is 2 271-2 053 hours, and the frost-free period is 109-141 days. The main tree species are *Pinus koraiensis*, *Tilia amurense*, *Fraxinus mandshurica*, *Acer mono*, *Quercus mongolica*, *Ulmus japonica* etc., the sub-ordinate tree is *Syringa reticulata* var. *mandshurica*. The shrubs include the *Corylus mandshurica*, *Philadelphus schrenki*, *Lonicera*

Foundation item: This research was supported by Institute of Shenyang Applied Ecology, CAS (SCXMS0101), National Key Technologies R&D Program (NKTRDP 2002BA516A20) and the Scientific Research Foundation for the Returned Overseas Chinese Scholars, Ministry of Education State.

Biography: JIN Yong-huan (1963-), male, Ph. Doctor, associate-professor in Institute of Applied Ecology, Chinese Academy of Science, Shenyang 110016, P. R. China

Received date: 2003-07-06

Responsible editor: Song Funan

chrysantha and so on. The ground layer include *Brachybotrys paridiformis, Maianthemum bifolium, Phryma leptostachya, Carex spp and Impatiens nolitangere* etc..

Study methods

Plot investigation

In 2002, 15 plots (32 m x 32 m), with different number of years after selective cutting (5, 10, 15, 19, 28 years), were set up in the natural secondary over-logged forest and 3 control plots were set up in the virgin forest. These plots selected have the same condition of stand to minimize the difference in the natural conditions of each logged forest. The cutting intensity of stand and mean diameter at breast height (DBH) after cutting were shown in Table 1. Altitude, slope, soil type as well as species, height, DBH, clear bole height and crown diameter for each tree more than 2 m in height were recorded for each plot. For the trees lower than 2 m in height, only species and height were recorded. Within each plot, 10 shrub plots (2 m×2 m) and 10 herb plots (2 m×2 m) were laid out separately, and the number, height, coverage of each shrub and the density, coverage, frequency of each herb were attentively investigated.

Table 1 The intensities of selective cutting for different investigated plots

Years after Selective cutting	Cutting intensity	Stand (DBH≥5 cm)	
	Stand volume /%	Mean DBH /cm	Mean height /m
5	36	17.8	20.1
10	33	18.0	17.9
15	45	15.9	15.2
19	43	15.2	16.0
28	42	20.7	16.4
Virgin forest	-	23.0	16.7

Selection and calculation of the diversity index

The richness index, diversity index (Shannon-Wiener index), and ecological dominance index (Simpson index) were adopted to calculate diversity (Ma 1995; Xie 1992). According to mean height of trees, the tree layer was divided into canopy layer (height≥15 m), secondary layer (15 m>height ≥ 1.5 m) and regeneration layer (height<1.5m). The diversities of the tree species in different layers were calculated separately by using the following equations

Richness index (S) = all the species in plot

Simpson index $D = \sum N(N-1)/n_i(n_i-1)$ (i=1,2...S)

Shannon-Wiener index $H' = -P_i \sum \ln P_i$ (i=1,2...S)

where: N is the individual number of all the species; n_i is the individual number of the ith species; P_i is the proportion of individual of ith, that is to say $P_i=n_i/N$; S is the number of species

Results and discussion

Change in tree species richness after selective cutting

The calculated results of Richness index (S) showed that for the whole stand there was no obvious change in species richness after selective cutting, with a richness index of 18-22, but for different layers in stand the change trend in species richness was quite different (Fig 1). After selective cutting, the species richness of the canopy layer increased by 15%-20% compared with that of virgin forest. For the regeneration layer, the species richness had a slow decrease at the early stage, decreased to 55% of that of the virgin forest at 10-15 years after selective cutting, and then gradually increased to the level of the virgin forest. The species richness of the secondary layer had a slow decrease and at 28 years after selective cutting it decreased to 74% of that of the virgin forest.

Disturbance appears to play important role in maintaining spatial heterogeneity of habitat and resources in landscapes (Canham 1985). Selective cutting, as an important disturbance to forest, often influences habitats, forest regeneration and tree growth. Our study results showed that changes of tree species richness after selective cutting were very small, thus the selective cutting was beneficial to the healthy development of forest ecosystem.

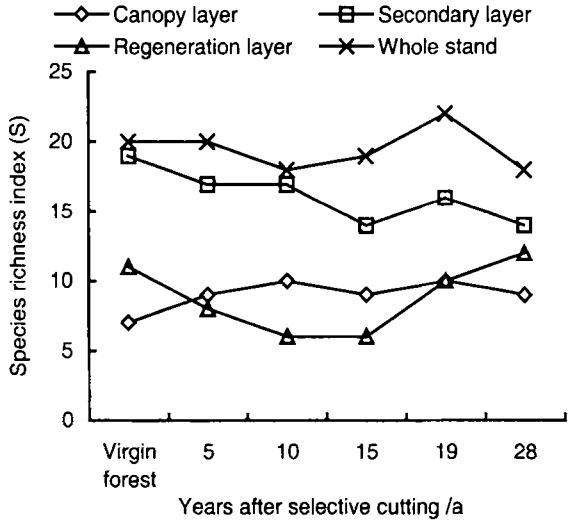

Fig.1 Change in tree species richness for different layer of stand in secondary forests after selective cutting

Ecological dominance after selective cutting

The Simpson indexes (D) of the regeneration and secondary layers and the whole stand changed, but in unison (Fig.2). By 5 years, the Simpson index (D) of regeneration layer was unchanged, while for the secondary layer and stand it descended rapidly. Thereafter, the Simpson indexes (D) of the three layers increased to plateau for the next decade before descending slightly. For the canopy

layer the Simpson index (D) steadily descended for 15 years and changed little thereafter; it was always lower than that of virgin forest. Moreover, there was a lag in the time each layer reached ecological dominance; the regeneration layer summitted 5 years ahead of the secondary layer and the secondary layer in turn summitted 5 years ahead of the whole stand.

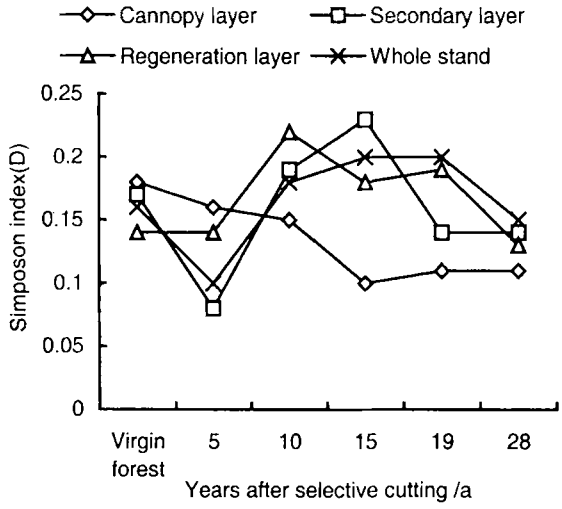

Fig.2 The dynamics of the ecological dominance in different layer and stand in secondary forests after selective cutting

Change of diversity index after selective cutting

The change of the diversity index was not very obvious after selective cutting. The change of Shannon-Wiener index (H') for different layers and the whole stand was in range of −10%-10% of that in the virgin forest. Shannon-Wiener index of different layers had different changing trends. For the canopy layer, Shannon-Wiener index increased gradually to plateau at 15 years after cutting and it was 1.2 times of that of the virgin forest at 28 years. As for the regeneration layer, the Shannon-Wiener index descended gradually in the first 10 years and then kept stable.

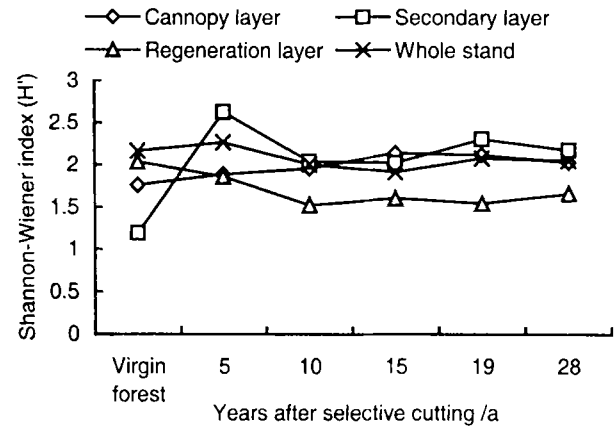

Fig.3 The dynamics of the diversity indexes for different layers and stand in secondary forests after selective cutting

The Shannon-Wiener index H′ reflects density, habitat, community type, and succession phases (Yan 1993). Magurran (1988) considered that H′ should be within 1.5-3.5. In natural secondary forests on the north slope of Changbai Mountain, the maximum value for H′ was 2.26 and the minimum value was 1.91. This indicated that the natural secondary forest in Changbai Mountain had high tree species diversity.

General discussion

Most of human-disturbed ecosystems usually have lower species diversity compared with the natural ecosystems. As a kind of human-disturbance, selective cutting may not only influence the habitat of community, but also alter the internal order of the plant community and the botanical composition of the forest. Moreover, it can also break down the competitive relationships and the co-dependence between some individuals. In the natural secondary forest, human-disturbance alters the response characters for the different tree species and layers. For example, 10 years after selective cutting, the ecological dominance of the natural secondary forest in Changbai Mountain had obvious change because the rapid growth of regenerating seedlings in large gaps created by a group of trees removed.

The restoration of the secondary forest was the process of natural succession of disturbed forest community. During the restoration, the organism and environment interact mutually, thus the forest community had special structure and function in different restoration stages, and the species diversity of different layers was also different. After being human-disturbed, the dynamic changes of the species diversity in canopy layer, secondary layer and regeneration layer could reflect the succession process of secondary forest community. Selective cutting creates a mosaic in the forest with patches of trees interspersed with small gaps from cutting, and those gaps offered the abundant living space for the trees and seedlings of secondary layer (Canham 1985). So the young seedlings numbers in secondary layer and regeneration layer of disturbed forest increased at the initial forest succession stage, and the ecological dominance index (Simpson indexes D) also increased rapidly. After 10-15 years, the increasing of herb and shrub in forest understory affected the growth of seedlings, as a result, the ecological dominance index (Simpson indexes D) decreased. From the dynamic change of Shannon-Wiener index, It could be concluded that seedlings quickly recruited under low intensity selective cutting make Shannon-Wiener index increased slowly during succession process. Thus, the mosaic created by selective cutting in the forest with patches of trees interspersed with small gaps from logging maintain the species diversity post logging forest (Denslow 1985).

Selective cutting, clear cutting and forest fire, etc. have different influences on forest. Selective cutting only caused a small-scale disturbance. Cutting intensity and cutting cycle were important factors to the change of arbor species

diversity and its dynamics. Our study showed that the selective-cutting forest had not recovered to the status of primary forest at 28 year after cutting. The present logging cycle needs to be reconsidered. In addition, the restoration of secondary forest after selective cutting was a complicated dynamic process. Many problems needed a thorough discussion, such as the dynamic change of spatial disturbance pattern of diversity index in different layers, and the change of component structure of stand during the 28 years restoration period after selective cutting, and so on.

Acknowledgements

We gratefully acknowledge recommendations made by anonymous reviewers and guest editor Song Funan on a previous version of this paper. We also thank Professor Kenneth C Hodgkinson of CSIRO Sustainable Ecosystems for suggestions for improvement to the original manuscript and Mr. Mu Qiang, Wang Jingtian and Li Taixing at Baihe Forestry Bureau of Jilin Province who gave numerous conveniences during field experiment.

References

Canham, C.D., Marks, P.L. 1985. The response of woody plants to disturbance: patterns of establishment and growth [C]. In: Pickett, S.T.A., White, P.S. (eds.), The ecology of natural disturbance and patch dynamics. Landon: Academic Press p197-216.

Denslow, J.S. 1985. Disturbance-mediated coexistence of species [C]. In: Pickett, S.T.A., White, P.S.(eds.), The ecology of natural disturbance and patch dynamics. London: Academic Press, p307-323.

Gao Baojia, Zhang Zhizhong, Li Zhenyu. 1992. The effect of closed forest on the structure and diversity of community [J]. Journal of Beijing Forestry University, **14**(2): 46-53. (in Chinese)

Gao Xianming, Huang Jianhui, Wan Shiqiang, *et al.* 1997. Ecological studies on the plant community succession on the abandoned cropland in Taibaisgan, Qinling mountains II. The community α diversity feature of the successional series [J]. Acta Ecologica Sinica, **17**(6): 619-625. (in Chinese)

Li Bo. 1997. The rangeland degradation in Northern China and its preventive strategy [J]. Scientia Agricultura Sinica, **30**(6): 1-9. (in Chinese)

Luo Juchun, Wang Qingsuo, Mu Chunsheng, *et al.* 1997. Plant diversity of *Pinus koraiensis* forests under disturbance in Changbai mountain of China [J]. Scientia Silvae Sinicae, **33**(6): 498-503. (in Chinese)

Ma Keping. 1995. Measurement of biotic community diversity [C]. In: Qian Yingqing and Ma Keping (eds), Principle and method of study on the biodiversity. Beijing: Science Press. P141-165 (in Chinese)

Maarten, K.A., Peer, A.F.K. & Rob, A.J., de Vries. 1995. Changes in diversity along a successional gradient in a costa rican upper montane *Quercus* forest [J]. Biodiversity and Conservation, **4**: 10-34.

Magurran, A.E. 1988. Ecological diversity and its measurement [M]. New Jersey: Princeton University Press. p43-47.

Shi Zuomin, Liu Shirong, Cheng Ruimei. 1998. Changes in plant species diversity in a restoration sequence of *Quercus Varaibilis* forest stand in Bao Tianman Mountain [J]. Acta Phytoecologica Sinica, **22**(5): 415-421. (in Chinese)

Xie Jinyang. 1992. Species diversity index and disturbance pattern of the species richness [C]. In: Lin Jinan (ed), Plants sciences. Harbin: Northeast Forestry University Press, p222-233.

Yan Guiqin, Bi Runcheng. 1993. The diversity and ecological dominance of forest community species in Shanxi Huoshan [J]. Journal of Southwest China Normal University (Natural Science), **18**(2): 173-178. (in Chinese)

Zhang Peichang, Zhou Xiaofeng, Wang Fengyou. 1999. Conspectus of the natural forest protects [M]. Beijing: China Forestry Press. p8-12(in Chinese)

Zhang Wanli, Li Leihong. 2000. Forest plant biological diversity and disturbance in eastern Heilongjiang forest areas [J]. Journal of Northeast Forestry University, **28**(5): 77-82. (in Chinese)